# GOES-R Space Weather L2+ Algorithm Development

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The NESDIS National Geophysical Data Center (NGDC) is currently responsible for the development of the GOES-R Level 2+ space weather science algorithms within the Risk Reduction and Algorithm Readiness programs. Close interaction with the user community represented by the NWS Space Weather Prediction Center (SWPC) ensures that the algorithms have operational relevance and, in some cases, can be immediately tested and deployed in the GOES-R Proving Ground. GOES-NOP data and space environmental measurements available from NASA science missions are used to produce proxy datasets and to allow "real-world" testing. The GOES-R algorithm developments have also been leveraged to provide early product demonstrations in the form of environmental assessments including spacecraft charging anomaly reports provided to NOAA senior leadership. In spite of the availability of space weather L2+ science algorithms it has yet to be determined where the operational processing will occur to support SWPC operations.

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## DEVELOPMENT TEAM

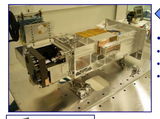
The NOAA National Geophysical Data Center (NGDC) is currently developing the Level 2+ space weather algorithms under the GOES-R Risk Reduction and Algorithm Readiness programs. These algorithms are being developed in cooperation with the NWS Space Weather Prediction Center (SWPC) who represents the operational users for the L2+ products (Figure below).

The L2+ algorithms are being developed by a dedicated affiliate team from the University of Colorado's Cooperative Institute for Research in Environmental Sciences (CIRES) overseen by a Federal advisory staff. Core team members from CIRES are:

| | |
|---|---|
| Mary Shouldis (NGDC) | Systems Engineering |
| Juan Rodriguez (NGDC) | SEISS |
| Alysha Reinard (SWPC) | EXIS |
| Janet Machol (NGDC) | EXIS |
| Jonathan Darnel (NGDC) | SUVI |
| William Rowland (NGDC) | MAG |
| Leslie Mayer (SWPC) | MAG/SEISS |
| Jim Vickroy (SWPC) | SUVI |

## GOES-R SPACE WEATHER SENSORS

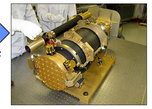
The space weather sensors for GOES-R represent a significant advancement in operational capability from GOES-NOP. The sensor complement will provide in-situ measurements of the space environment in terms of energetic charged particles (electrons, protons and heavier ions) and the local magnetic field. Also included are solar-viewing sensors to image the sun in the ultraviolet and to measure radiant emissions in both x-rays and ultraviolet. Threshold capabilities for the GOES-R space weather sensors were derived from a series of user workshops held during the GOES-R concept exploration phase.



***EUV and X-Ray Irradiance Sensors (EXIS)***

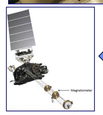
- Extreme Ultraviolet Sensor (EUVS)
- X-Ray Sensor (XRS)
- EUVS/XRS Electrical Box (EXEB)
- Sun Positioning Sensor (SPS)

*Sensor Manufacturer: LASP*



***Solar UltraViolet Imager (SUVI)***

*Sensor Manufacturer: LMATC*



***Magnetometer (MAG)***

*Sensor Procurement: LM*

***Space Environment In-Situ Sensor (SEISS)***

Magnetospheric Particle Sensor Low (MPS-LO)
Magnetospheric Particle Sensor High (MPS-HI)
Solar & Galactic Proton Sensor (SGPS)
Energetic Heavy Ion Sensor (EHIS)

*Sensor Manufacturer: ATC*

Level 2+ space weather algorithms initially recommended for development by SWPC and subsequently approved by the GORWG are listed below for Product Sets 1 to 3. The Product Sets represent both improvements to legacy GOES-NOP algorithms and new products all of which take full advantage of the GOES-R advanced sensing capabilities. Product Sets 1 and 2 are now complete and ready for operational implementation. Currently under development within NGDC are those science algorithms listed in Product Set 3.

**Product Set 1 Complete**

- **XRS.04: One-minute averages for both long and short channels**
- **EUVS.03: One-minute averages of broad spectral bands**
- **SEISS.16: One-minute averages - all MPS channels**
- **SEISS.17: Five-minute averages - all MPS and SGPS channels**
- **SEISS.18: Convert differential proton flux values to integral flux values**
- **MAG.07: MAG data in alternate geophysical coordinate systems**
- **MAG.08: One-minute averages**
- **MAG.09: Comparison to quiet fields**
- **SUVI.07: Composite (wide dynamic range) images**
- **SUVI.09 and .10: Fixed and running difference images**

**Product Set 2 Complete**

- **XRS.05: Calculate the ratio of the short over long channels**
- **XRS.09: Daily Background**
- **XRS.07: Event Detection with one-minute data**
- **EUVS.03D: Daily averages of broad spectral bands**
- **EUVS.04: Event Detection**
- **SEISS.19: Density & temperature moments & level of spacecraft charging**
- **MAG.10: Magnetopause crossing detection**
- **SUVI.12: Coronal Hole Images**
- **SUVI.19: Thematic Map**

Legacy Product
New Product

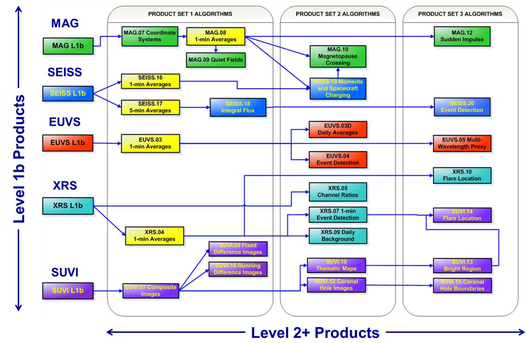
**Product Set 3 In Process**

- **XRS.10: Flare Location**
- **EUVS.05: Multi-wavelength Proxy**
- **SEISS.20: Event detection based on flux values**
- **MAG.12: Sudden Impulse (SI) detection**
- **SUVI.13: Bright Region Data**
- **SUVI.14: Flare Location (XFL) Reports**
- **SUVI.15: Coronal Hole Boundaries**

*Algorithms leverage new sensor capabilities and extended environmental ranges.*

- 26 Level 2+ Space Weather Products in three product sets
- 18 are operational legacy, 8 are new or have experimental heritage

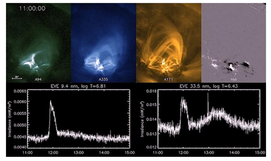
Product Sets 1 to 3 represent an interdependent set of algorithms which increase in complexity from simple averaging and image differencing in Product Set 1 to image composite analyses and geophysical interpretations in Product Set 3.



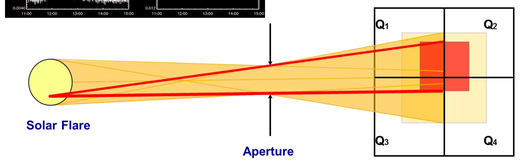

## Product L1b/L2+ Interdependencies

## SET 3 SELECTED PRODUCT DESCRIPTIONS

### XRS.10 Flare Location

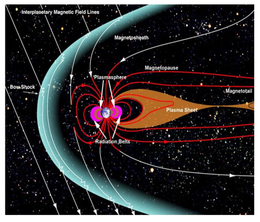


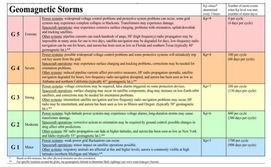
New quad-diode XRS design will provide an ability to locate solar flares on the disk. Algorithm will automate the locations of solar flares to aid in predicting impacts to earth-based and satellite systems. Proxy data from the GOES SXI and/or SDO EVE will be used to develop this new approach.




### MAG.12 Sudden Impulse Detection

Algorithm to detect impulsive magnetospheric events. GOES-R data to be used in conjunction with ground magnetometer observations to detect events. Outputs used for SWPC geomagnetic storm warning.



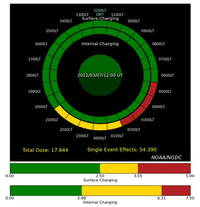



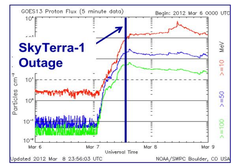

Destroyed Power Transformer – March 1989

## LEVERAGED USE OF THE GOES-R PRODUCTS (EXAMPLE)

### Environmental Assessments

On March 7th, 2012 the SkyTerra-1 satellite suffered an anomaly causing a COMM outage that adversely impacted homeland security readiness. Using tools developed under the GOES-RRR/AR program, NGDC conducted an environmental assessment that showed that the SkyTerra-1 was at increased risk of experiencing a Single Event Upset (SEU) .



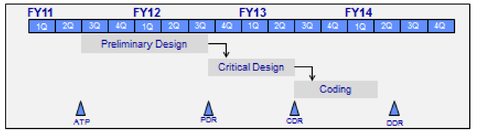




## DEVELOPMENTAL SCHEDULE

The developmental schedule for Product Set 3 is shown below. The algorithm team members are currently working with the space weather operators within SWPC on the detailed requirements for the algorithms. The requirements are being captured in a GOES-R SWx L2+ Algorithm Requirements Document coordinated between NGDC and SWPC. Final deliveries of the Product Set 3 algorithms are currently planned for 2QFY14. As noted earlier, the path for research to operations (R2O) is currently unknown.

### GOES-R Space Weather
### Product Set 3 – Schedule

| Product | Description | PDR | CDR | DDR |
|---|---|---|---|---|
| XRS.10 | Flare Location | 08/2012 | 3QFY13 | 2QFY14 |
| EUVS.05 | Multi-wavelength Proxy | 08/2012 | 3QFY13 | 2QFY14 |
| SEISS.20 | Event Detection | 08/2012 | 3QFY13 | 2QFY14 |
| MAG.12 | Sudden Impulse Detection | 08/2012 | 3QFY13 | 2QFY14 |
| SUVI.13 | Bright Region Data | 08/2012 | 3QFY13 | 2QFY14 |
| SUVI.14 | Flare Location Reports | 08/2012 | 3QFY13 | 2QFY14 |
| SUVI.15 | Coronal Hole Boundaries | 08/2012 | 3QFY13 | 2QFY14 |




GOES Science Week – 2012

## CONCLUSIONS

- Activities in Year 1 were focused on requirements definition in cooperation with the operational user (SWPC)
- Current Year 2 activities include Preliminary / Critical Design Review (PDRs/CDRs) for the 7 products currently under development
- Year 3 activities involve final algorithm coding (science) and Data Delivery Reviews (DDRs)